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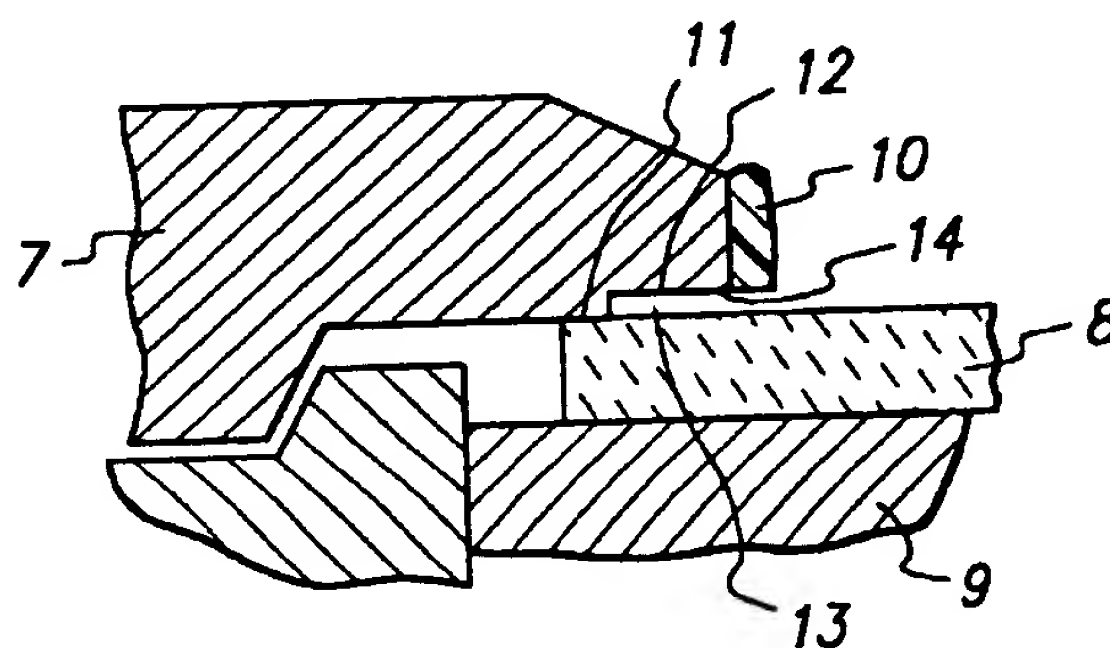
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: <b>PCT/US94/08476</b> (22) International Filing Date: <b>26 July 1994 (26.07.94)</b> (30) Priority Data: <b>08/099,314</b> <b>30 July 1993 (30.07.93)</b> <b>US</b> (71) Applicant: <b>LAM RESEARCH CORPORATION [US/US];</b> <b>4650 Cushing Parkway, Fremont, CA 94538-6401 (US).</b> (72) Inventors: <b>LENZ, Eric, Howard; 3247 La Donna, Palo Alto,</b> <b>CA 94306 (US). BRUMBACH, Henry; 235 Addison Court,</b> <b>Fremont, CA 94539 (US).</b> (74) Agents: <b>PETERSON, James, W. et al.; Burns, Doane, Swecker</b> <b>&amp; Mathis, P.O. Box 1404, Alexandria, VA 22313-1404</b> <b>(US).</b></p>		<p>(81) Designated States: <b>JP, KR, European patent (AT, BE, CH, DE,</b> <b>DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</b>  <b>Published</b> <i>With international search report.</i></p>

(54) Title: **SHADOW CLAMP**

(57) Abstract

A wafer clamping member (7) for clamping a wafer (8) in a plasma reaction chamber. The clamping member (7) has a design which minimizes particle contamination of the wafer (8) and allows more wafers to be processed before it is necessary to clean built-up deposits (10) from the clamping member (7). The clamping member (7) includes a clamping portion (11) which clamps an outer periphery of the wafer (8) against a bottom electrode (9) and a shadow portion (12) which provides a gap (13) between an inner edge (14) of the clamping member (7) and the upper surface of the wafer (8). The gap (13) is open to the interior of the plasma reaction chamber and preferably has a height equal to about the mean free path of a gas activated to form a plasma in the plasma reaction chamber.



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## SHADOW CLAMP

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The invention relates to a wafer clamping device which can  
5 be used in a plasma reaction chamber as well as a method of  
clamping wafers.

#### 2. Description of Related Art

Ring clamps for clamping wafers against electrodes in  
plasma etching chambers are disclosed in U.S. Patent Nos.  
10 4,615,755 and 5,013,400, the disclosures of which are hereby  
incorporated by reference.

Figure 1 shows a cross section of a conventional wafer  
clamping device in a plasma reaction chamber wherein a wafer  
clamp 1 presses an outer periphery of a wafer 2 against an  
15 electrode 3. During processing (e.g. etching, coating, etc.) of  
wafers in the chamber, by-products of the process result in a build-  
up of a deposit 4 (such as a polymer build-up during etching of the  
wafer) on an edge of the clamp 1 in contact with the wafer 2. The  
deposits 4 must be removed periodically in order to prevent particle  
20 contamination of the wafers. That is, due to rubbing contact  
between a clamping surface 5 of the clamp 1 and an upper surface  
6 of the wafer 2 during wafer transfer, particles of the deposit 4  
break off and fall onto the surface 6 of the wafer being processed.  
Accordingly, it is necessary to frequently shut down the plasma  
25 reaction chamber and clean the wafer clamping apparatus in order  
to avoid the particle contamination problem.

There is a need in the art for a wafer clamping apparatus which does not suffer from the disadvantages described above of the conventional wafer clamping device. That is, a clamping member which allows the plasma reaction chamber to run a significantly longer time before cleaning of the clamp becomes necessary would provide higher quality wafers due to reduced particle contamination and would provide economic benefits in allowing more efficient use of the equipment due to reduced down time for chamber/clamping member cleaning.

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### SUMMARY OF THE INVENTION

The invention provides an improved clamping design for clamping a wafer in a plasma reaction chamber. In particular, the clamping member includes a clamping portion and a shadow portion. The clamping portion is capable of clamping against an outer periphery of a wafer in the plasma reaction chamber and the shadow portion extends over the wafer such that an open gap is formed between the wafer and the shadow portion. The gap is in fluid communication with the interior of the plasma reaction chamber and functions to inhibit built-up deposits on the clamping member from contacting the wafer during clamping and processing of wafers. Thus, the clamping member can operate a significantly longer time without particle contamination of the wafers compared to a clamping member which does not include such a gap.

According to various features of the invention, the gap can be dimensioned such that an inner edge of the clamp is spaced above the wafer by a distance equal to about a mean free path of a

gas activated to form a plasma in the plasma reaction chamber.

The gap can have a length in a direction parallel to a major surface of the wafer greater than a height of the gap between the wafer and the inner edge of the clamp. The length can be at least two times

5 or even up to five times or greater than the height. According to a preferred embodiment, the gap has a height of 0.005 to 0.030 inch, this height extending between the wafer and a surface of the shadow portion facing the wafer. When the height is equal to about a mean free path of a reactant gas used in the plasma reaction  
10 chamber, the gap functions to retard growth of built-up deposits on the clamping member in a direction towards the wafer. That is, the deposits tend to build-up in directions which extend parallel to the wafer surface and away from the wafer surface thereby maintaining a gap between the built-up deposit and the wafer surface. Thus,  
15 particle contamination of the wafer can be avoided.

According to one aspect of the invention, the clamping member can comprise a single piece of material. According to another embodiment of the invention, the clamping member can  
20 comprise first and second discrete pieces wherein the clamping portion is part of the first piece and the shadow portion is part of the second piece. The second piece can include a support surface attached to the first piece and a shadow surface which is exposed and extends away from the first piece so as to face the wafer with the gap therebetween.

25 The plasma reaction chamber can include at least one gas inlet means for introducing processing gas into the reaction chamber and plasma generating means for activating the process

gas to form a plasma in the reaction chamber. Thus, according to the invention a wafer can be treated in the plasma reaction chamber by clamping the clamping member against an outer periphery of the wafer and the wafer can be treated by introducing a plasma  
5 processing gas into the plasma reaction chamber and activating the processing gas with the plasma generating means to form a plasma whereby the wafer can be processed (e.g., etched, coated, etc.). The method can also include a step of cleaning deposits such as polymer build-up on the clamping member when such deposits  
10 substantially close the gap between the wafer and the shadow portion of the clamping member.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 shows a conventional clamping member clamping an outer periphery of a wafer against a bottom electrode in a plasma  
15 reaction chamber;

Fig. 2 shows a one-piece clamping member in accordance with the invention wherein a gap is provided between the inner edge of the clamping member and an upper surface of the wafer;  
and

20 Fig. 3 shows another embodiment of a clamping member in accordance with the invention wherein the clamping member is provided in two separate pieces.

**DETAILED DESCRIPTION OF**  
**THE PREFERRED EMBODIMENTS**

In the following description, a wafer clamping member is described with reference to clamping a wafer in a plasma etching apparatus. However, the clamping member can be used in other plasma reaction chambers wherein deposition or other treatments are carried out.

In plasma etching it is often necessary to mechanically clamp wafers to the lower electrode for cooling the wafer with a thermally conductive gas at higher pressures than the etching chamber. Plasma etching can also create large amounts of polymeric compounds that deposit on the surface of the mechanical clamp and the surfaces of the chamber. These polymeric compounds are not as much of a problem on the chamber walls as they are on the clamp. The clamp, because of its movement with every wafer transfer, is a problem in that it can shed some of this polymer as a result of rubbing of surfaces.

Clamping systems have had problems with particles being shed on to the wafer at fairly short intervals after being cleaned. The shadow clamp according to the invention greatly increases the times between occurrence of particle problems. In particular, the shadow clamp controls the problem of the polymer that is deposited on the inner edge of the clamp. This polymer is a problem because it will touch the wafer and has a chance of being knocked off every time a wafer is clamped. The shadow clamp allows polymer to grow on the inner edge of the clamp, but the polymer does not touch the wafer. The shadow clamp accomplishes this by raising

the inner edge of the clamp above the wafer. For instance, the inner edge can be located above the wafer by a distance on the order of the mean free path of the etch chamber gas. Further, the first contact point between the wafer and the clamp can be located  
5 away from the inner edge by a distance equal to two to five times the height that the inner edge is raised.

The polymer that builds on the front edge of the shadow clamp builds in both the vertical and horizontal directions. The polymer that builds in the vertical direction eventually touches the  
10 wafer and creates particles, but this takes on the order of 6 times the time it takes for particles to cause particle contamination on a conventional clamp such as the clamp shown in Figure 1. As an example, the clamp shown in Figure 1 must be cleaned after 500 minutes of plasma etching whereas it is not necessary to clean the  
15 shadow clamp for 3000 minutes since the narrow initial gap between the inner edge of the shadow clamp and the wafer prevents polymer from growing on the edge of the clamp that touches the wafer.

Figure 2 shows an embodiment of a one-piece clamping  
20 member 7 in accordance with the invention. In particular, the clamping member 7 is engageable with an outer periphery of a wafer 8 whereby the wafer 8 can be clamped against an electrode 9. During processing of wafers, by-products of the plasma treatment result in a build-up of a deposit 10 on the clamping  
25 member 7. In order to avoid the particle contamination problem of conventional clamping members, clamping member 7 includes a clamping portion 11 and a shadow portion 12. As shown in Figure



2, the clamping portion 11 presses against an outer periphery of the wafer 8 and the shadow portion extends over the wafer 8 such that an open gap 13 is formed between the wafer 8 and the shadow portion 12. According to a preferred embodiment, the gap 13 is dimensioned such that an inner edge 14 of the clamp 7 is spaced  
5 above the wafer 8 by a distance equal to about a mean free path of a gas activated to form a plasma in the plasma reaction chamber.

Figure 3 shows an embodiment of a two-piece clamping member 15 in accordance with the invention. In particular, the  
10 clamping member 15 is provided in two separate pieces 16, 17 with the clamping portion 11 forming part of the first piece 16 and the shadow portion 12 forming part of the second piece 17. The second piece 17 includes a support surface 18 and a shadow surface 19. The support surface 18 is attached by any suitable means to  
15 the first piece 16 and the shadow surface 19 is an exposed surface which extends away from the first piece 16 and faces a wafer clamped by the clamping member 15.

The foregoing has described the principles, preferred embodiments and modes of operation of the present invention.  
20 However, the invention should not be construed as being limited to the particular embodiments discussed. Thus, the above-described embodiments should be regarded as illustrative rather than restrictive, and it should be appreciated that variations may be made in those embodiments by workers skilled in the art without  
25 departing from the scope of the present invention as defined by the following claims.

**WHAT IS CLAIMED IS:**

1. A clamp for clamping a wafer in a plasma reaction chamber, comprising:

5 a clamping member including a clamping portion and a shadow portion, the clamping portion being capable of clamping against an outer periphery of a wafer in a plasma reaction chamber with the shadow portion extending over the wafer such that an open gap is formed between the wafer and the shadow portion and the gap is in fluid communication with an interior of the plasma  
10 reaction chamber.

2. The clamp of Claim 1, wherein the gap is dimensioned such that an inner edge of the clamp is spaced above the wafer by a distance equal to about a mean free path of a gas activated to form a plasma in the plasma reaction chamber.

15 3. The clamp of Claim 1, wherein the gap has a length in a direction parallel to a major surface of the wafer greater than a height of the gap between the wafer and an inner edge of the clamp.

20 4. The clamp of Claim 3, wherein the length is at least two times greater than the height.

5. The clamp of Claim 3, wherein the length is at least five times greater than the height.

25 6. The clamp of Claim 3, wherein the height is equal to about a mean free path of a reactant gas used in the plasma reaction chamber.

7. The clamp of Claim 1, wherein the clamping member comprises first and second separate pieces, the clamping

portion being part of the first piece and the shadow portion being part of the second piece.

8. The clamp of Claim 7, wherein the second piece includes a support surface and a shadow surface, the support surface being attached to the first piece and the shadow surface being an exposed surface extending away from the first piece and facing the wafer.

9. The clamp of Claim 1, wherein the gap has a height of 0.005 to 0.030 inch between the wafer and a surface of the shadow portion facing the wafer.

10. A plasma reaction chamber having a wafer clamping member which minimizes particle contamination of wafers processed in the plasma reaction chamber and allows cleaning of the clamping member to be performed more infrequently, comprising:

a plasma reaction chamber including at least one gas inlet means for introducing processing gas into the reaction chamber and plasma generating means for activating the processing gas to form a plasma in the reaction chamber; and

a clamping member including a clamping portion and a shadow portion, the clamping portion being capable of clamping against an outer periphery of a wafer in the plasma reaction chamber with the shadow portion extending from the clamping portion over the wafer such that an open gap is formed between the wafer and the shadow portion, the gap being in fluid communication with an interior of the plasma reaction chamber.

11. The clamp of Claim 10, wherein the gap is dimensioned such that an inner edge of the clamp is spaced above the wafer by a distance equal to about a mean free path of a gas activated to form a plasma in the plasma reaction chamber.

5 12. The clamp of Claim 10, wherein the gap has a length in a direction parallel to a major surface of the wafer greater than a height of the gap between the wafer and an inner edge of the clamp.

10 13. The clamp of Claim 12, wherein the length is at least two times greater than the height.

14. The clamp of Claim 12, wherein the length is at least five times greater than the height.

15 15. The clamp of Claim 12, wherein the height is equal to about a mean free path of a reactant gas used in the plasma reaction chamber.

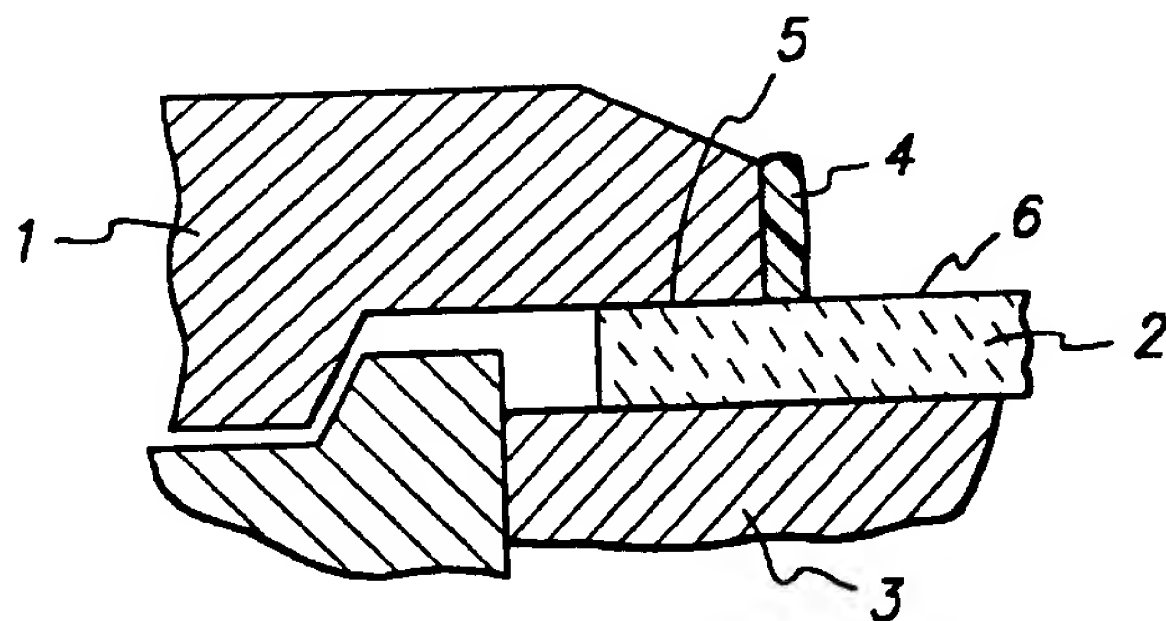
16. The clamp of Claim 10, wherein the clamp comprises first and second separate pieces, the clamping portion being part of the first piece and the shadow portion being part of the second piece.

20 17. The clamp of Claim 16, wherein the second piece includes a support surface and a shadow surface, the support surface being attached to the first piece and the shadow surface being an exposed surface extending away from the first piece and facing the wafer.

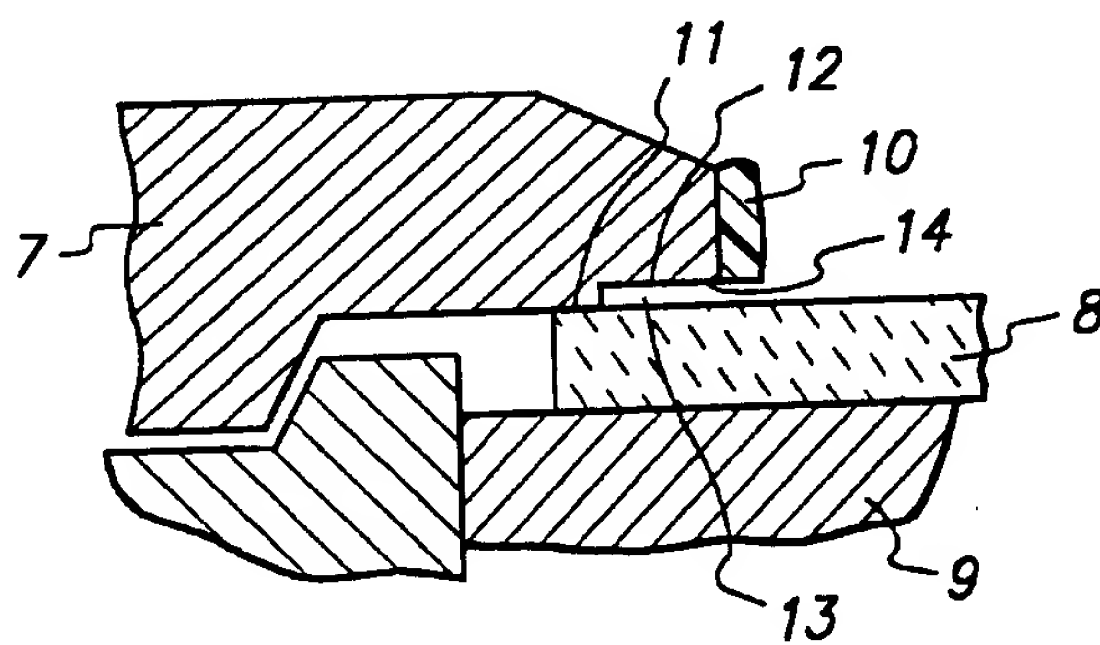
25 18. The clamp of Claim 10, wherein the gap has a height of 0.005 to 0.030 inch between the wafer and a surface of the shadow portion facing the wafer.

19. A method of treating a wafer in a plasma reaction chamber, the plasma reaction chamber including at least one gas inlet means for introducing processing gas into the reaction chamber and plasma generating means for activating the processing gas to form a plasma in the reaction chamber, comprising steps of:
- 5 clamping a clamping member against an outer periphery of a wafer in the plasma reaction chamber, the clamping member including a clamping portion and a shadow portion, the clamping portion being clamped against the outer periphery of the wafer and the shadow portion extending over the wafer with a gap between the wafer and the shadow portion, the gap being in fluid communication with an interior of the plasma reaction chamber and the gap being dimensioned to prevent built-up deposits on an inner edge of the clamping member from contacting the wafer during the
- 10 clamping step; and
- 15 treating the wafer by introducing a plasma processing gas into the plasma reaction chamber and activating the processing gas with the plasma generating means to form plasma.
20. The method of Claim 19, further comprising a
- 20 cleaning step wherein built-up deposits are removed from the clamping member when the deposits substantially close the gap between the wafer and the shadow portion of the clamping member.

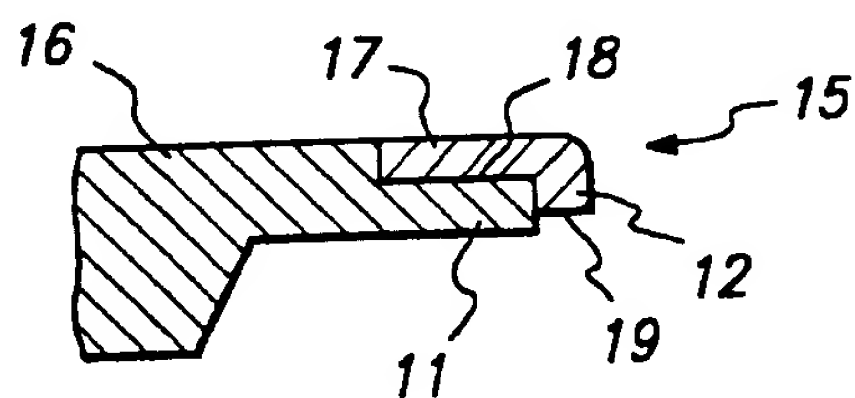
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**FIG. 1** PRIOR ART



**FIG. 2**



**FIG. 3**

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US94/08476

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : H01L 21/68

US CL : 156/345, 643; 118/500, 503; 204/298.15; 414/941; 269/315,316

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 156/345, 643; 118/500, 503, 728; 204/298.15; 414/941; 269/315, 316, 329, 903

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP,A, 5-109879 (KOIKE) 30 April 1993. See the English Abstract.	1, 3, 7, 8
X — Y	US,A, 4,978,412 (AOKI ET AL) 18 December 1990. See Figs. 8-10.	1-8, 10-17 ----- 9, 18
A,P	US,A, 5,262,029 (ERSKINE ET AL) 16 November 1993. See the entire document.	1-20

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search

18 OCTOBER 1994

Date of mailing of the international search report

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